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Subject: CSM Extension of ADJ-2-30630-05, Studies of Basic Electronic Properties of CdTe-based Solar Cells.

Principal Investigators and key personnel: Dr. Joseph D. Beach Jr.
Dr. Victor Kaydanov
Dr. Timothy R. Ohno
Dr. Fred H. Seymour

Dear Ken,

During the second quarter of the subcontract extension (1 February 2006 - 30 April 2006) the following work was performed.

Task 1. Study of Deep Electronic States controlling V_{OC}.

The goal of this deep electronic states (DES) study is to detect, characterize, and identify DES that can either limit or enhance V_{OC} in order to help cell growers modify their processes to produce better devices. During the 2nd quarter additional cells received from B. McCandless at the Institute for Energy Conversion were analyzed. We have now examined cells with admittance spectroscopy from four separate sources that had post-deposition processing with and without intentionally added Cu and $CdCl_2$. Two sources had CSS deposited CdTe and the other two had VTD deposited CdTe. The CSM gas jet VTD system was one of the sources. From this dataset we have made a number of observations and we have a publication in press that discusses this[1].

In summary, all of the cells with V_{OC} significantly greater than 700 mV had discrete energy level deep electronic states (DES) that we could detect with our admittance spectroscopy equipment. All of the cells with V_{OC} significantly less than 700 mV did not. These discrete energy level DES include the V_{Cd}^{-} and the A-center complex V_{Cd}^{2-} Cl_{Te}^{+} acceptor defects with $E_a \sim 0.15$ eV and the Cu_{Cd}^{-} acceptor defect with $E_a \sim 0.35$ eV. The capacitance measurements at elevated temperatures indicate that generally the better performing cells have a higher space charge density in the depletion region and a lower concentration of mid-gap DES that can contribute to SRH recombination.

Task 2. Test different cell growth approaches that can lead to higher V_{OC}.

We organized and facilitated a mini-workshop on raising V_{OC} at the March CdTe National Team meeting. The goal of this session was to focus team attention on the problems with raising V_{OC} as well as to propose and evaluate new ideas for raising V_{OC}. The two hour session included presentations on the device physics of raising V_{OC} by Victor Karpov, Jim Sites and Alan Fahrenbruch, and on the cell fabrication aspects of raising V_{OC} by Brian McCandless, Chris Ferekides, and Xuanzhi Wu. This was followed by a discussion and a written survey seeking ideas on how to raise V_{OC}.

A total of 37 ideas were tabulated, distributed to the team, and they will be incorporated into the meeting minutes. Ideas ranged from standard processing procedures practiced by all cell growers to those that have never been tried. The list was divided into six major categories of V_{OC} limiting problems. For each category the root causes, models/symptoms/effects, and possible remedies were listed. Within each possible remedy the institutions that are working on it or have worked on it along with a principal contact were also listed. The six categories were:
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1) Lateral non-uniformities
2) Back contact barrier
3) Increasing doping concentration
4) Reducing SRH recombination
5) Window layer/heterojunction losses
6) Other

The information gathered during this mini-workshop will be very helpful as we proceed with testing ideas to raise V_{OC} using the CSM gasjet VTD system.

Sincerely,

Fred H. Seymour

References

[1]F. H. Seymour, V. Kaydanov, T. R. Ohno, "Admittance Spectroscopy Characterization of Deep Electronic States in Cadmium Telluride Solar Cells", to be published in the proceedings from the 2006 IEEE 4th World Conference on Photovoltaic Energy Conversion.